

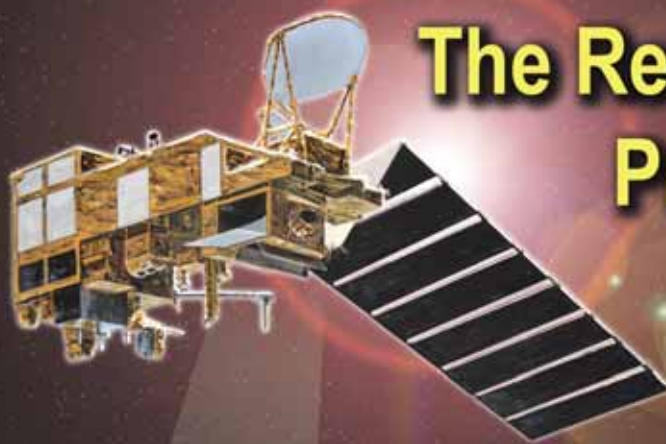
# ENVIROCAST

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NP  ESS

**The Restructured  
Program for  
Improved  
Weather  
Forecasts**



# The Restructured Program for Improved Weather Forecasts

Dave Jones and Craig Nelson

**T**his is the first in a series of articles describing the recently restructured program for the National Polar-orbiting Operational Environmental Satellite System (NPOESS). NPOESS will replace the Department of Defense's Defense Meteorological Satellite Program (DMSP) and the National Oceanic and Atmospheric Administration's Polar-orbiting Operational Environmental Satellites (POES) that have provided global data for weather forecasting and environmental monitoring for over 40 years. NPOESS will acquire and deliver critical Earth observation measurements to central processing facilities through an innovative global communications network of 15 unmanned ground stations that will provide significantly improved data latency. NPOESS will enable high-quality, space-based, remotely-sensed data to be used faster and more frequently in numerical weather prediction models for improved environmental forecasts and warnings.

NPOESS is being developed for joint operational use by civilian and military agencies. The first satellite of the restructured program is expected to be launched in 2013. NPOESS will be critical to our national security and to our ability to monitor global environmental changes. Data from the advanced NPOESS sensors will support the war fighter; improve weather forecasts, and address our changing climate in ways that will enable more efficient and improved commerce while preparing us for the dangers that Mother Nature throws our way every day.

## Introduction

When Tropical Storm Katrina emerged from southern Florida into the southeastern Gulf of Mexico early on Friday morning, August 26, 2005, she quickly regained hurricane strength by 5AM. There was much uncertainty about where she would strike next. Forecasters had their eyes on the western Florida panhandle as hurricane models predicted that the storm would turn rather quickly toward the north. It looked like landfall was possible near the panhandle of Florida sometime late morning or early afternoon on Monday, August 29, 2005 with winds just over 100 mph.

Most weather forecasters around the nation, including Max Mayfield, Director of the National Oceanic and Atmospheric Administration's (NOAA) National Hurricane Center (NHC) would have given anything to know when and where Katrina (and any hurricane) would eventually strike. An even bigger question was...how strong would Katrina be when she hit? Conditions seemed very ripe for intensification and NHC



**Max Mayfield**, Director of the National Hurricane Center analyzes the latest data and information prior to going on-air into the homes of millions of people. Hurricane Katrina rapidly developed into a category 5 hurricane, the most intense category on a scale from 1 to 5. Max and the forecasters at NHC performed superbly during Katrina but more data is needed to increase the accuracy of hurricane track and intensity forecasts beyond 2 days.

forecasters were hinting that Katrina could become a major hurricane prior to landfall "somewhere along the northern Gulf coast." Accurate weather forecasts save lives and property. Huge economic benefits are realized when hurricane landfall and intensity are accurately forecast two to five days in advance.

Hurricane Katrina made landfall at around 7AM on Monday, August 29, 2005 near Buras, LA, 172 nautical miles west of the initial forecast that was made 72 hours earlier. Katrina was a strong category 3 hurricane with sustained winds of 110 knots (127 mph). The 172 nautical mile track error 72 hours out is better than the average forecast track error. The NHC issued a very reasonable forecast that Friday morning given the state of the science, availability of observations, accuracy of today's weather forecast models, and skill levels of the forecasters. When Katrina moved further into the Gulf of





*The forecast issued by the National Hurricane Center at 5 AM EDT August 26, 2005. Initial forecasts had Katrina heading toward the panhandle of Florida. Subsequent forecasts as Katrina moved into the Gulf of Mexico trended toward New Orleans and Southeast Louisiana. The cone of uncertainty is outlined in white.*

Mexico, NHC predicted with great accuracy where Katrina was eventually going to hit.

Katrina was a large and intense hurricane that struck a portion of the coast along the northern Gulf of Mexico that is particularly vulnerable to storm surge, leading to loss of life and property damage of immense proportions. The scope of human suffering inflicted by Hurricane Katrina in the United States has been greater than that of any hurricane to strike this country in several generations.

The goal of NOAA and its parent agency, the Department of Commerce (DOC), is to reduce the uncertainty in any particular weather forecast farther out in time to enable decisions that will minimize human and economic impacts. Forecast accuracy will improve through better understanding and modeling of the global interactions among the atmosphere, ocean, land, and cryosphere. Ultimately, this will require more global environmental observations taken at higher fidelity (improved resolution, accuracy, and precision) and higher frequency than the observations that are being collected today.

### Reducing Uncertainty

When a hurricane, such as Katrina, approaches the coastline NOAA issues a forecast of where the storm is expected to strike and how intense it is expected to be. The hurricane warning is based primarily on numerical weather prediction (NWP) models that use satellite, aircraft, and land/ocean-based in situ observations to represent the current or "initial"



*The VIIRS sensor on NPOESS will deliver spectacular images such as this taken of hurricane Katrina. This image was taken with the VIIRS precursor instrument on EOS Aqua on August 28, 2005 at 1:00 PM EDT.*

state of the atmosphere, oceans, land, and cryosphere, and mathematical equations solved on super computers to predict the evolution of the storm in time. If scientists do not have accurate data to represent the "initial" state, uncertainty is introduced into the model and this uncertainty grows with time. Because weather forecasting is not an exact science and the amount of data available to construct an accurate "high definition" picture of the atmosphere, oceans, land, and ice is not adequate today, a "cone of uncertainty" accompanies the official NHC forecast (fig. 2).

This cone defines the areas that are most threatened by the storm along its predicted track. The track and cone are updated with every forecast cycle. The

problem with this kind of product is that when it comes time for emergency managers to determine if a full-scale evacuation should be ordered, uncertainty always enters the picture. People do not want to be evacuated every time a hurricane enters the Gulf of Mexico. Pinpointing landfall to within a few miles along a densely populated coast is critical, but nearly impossible today, especially three to five days out. The tendency is to "wait for the next update." However, evacuation times continue to increase due to expanding coastal populations. Should emergency decision makers wait or order an evacuation now?

### A "High Definition" Picture

Today NOAA and the Department of Defense (DoD) operate two similar but independent polar-orbiting "weather" satellites. NOAA's Polar-orbiting Operational Environmental Satellites (POES) and DoD's Defense Meteorological Space Program (DMSP) spacecraft orbit the Earth at an altitude of 833 km (~450 nm) from pole to pole approximately 14 times each day and are able to scan almost the entire surface of the Earth twice daily. Instruments mounted on the satellites continually collect and distribute a wealth of data to users such as scientists, researchers, weather forecasters, military personnel, emergency management officials, space weather scientists, and rescue workers. The data collected by instruments on NOAA's POES are critical to determining the initial state of the atmosphere for input into NWP models. This input is critical to maximize the accuracy of model forecasts both locally and globally. The forecasts produced by these models are the foundation of products used to inform and protect the U.S. public. The DoD's DMSP spacecraft primarily supply weather and other environmental information to support military operations globally.

The future of NOAA's and DoD's polar-orbiting weather satellite programs is the National Polar-orbiting Operational Environmental Satellite System (NPOESS). NPOESS is being developed to employ next-generation platforms and instruments in an integrated mission serving the nation's needs for space-based, remotely-sensed environmental data. By gathering data at higher resolutions and

frequency than are available with today's systems, NPOESS will contribute significantly to improving the accuracy of global, regional, and local weather forecasts farther out in time. The Department of Commerce, Department of Defense, and the National Aeronautics and Space Administration (NASA) jointly created the NPOESS Integrated Program Office (IPO) in 1995 to develop, acquire, manage, and operate NPOESS. DoD and NOAA are sharing the cost of building and operating NPOESS, while NASA is contributing its technology and expertise. The prime contractor for the program is Northrop Grumman Space Technology (NGST) and Raytheon is the largest subcontractor. With NOAA, DoD, and NASA all playing integral roles, the tri-agency NPOESS program promises greater coordination and a wider applicability for the nation's environmental satellite programs.

The NPOESS program was recently restructured when it was certified by the DoD based on a tri-agency review including DOC and NASA under the Nunn-McCurdy process. NPOESS was determined to be essential to national security and executable under the revised cost and management plan.

### NPOESS: An "End-to-End" System

NPOESS represents a major upgrade to the existing NOAA and DoD polar-orbiting weather satellites. NPOESS spacecraft will carry a complement of advanced imaging and sounding sensors that will acquire data at much higher fidelity and frequency than are available today. While sensors are the "business" end of the system, other critical components are needed to transform "raw" data collected in space into products that can be delivered easily and quickly to civilian and military users on the ground. NPOESS will employ a very innovative data collection and processing system to accomplish this task. The "end-to-end" system includes: sensors; spacecraft; command, control, communications, data routing; and ground processing.

The NPOESS spacecraft will carry improved imaging and sounding sensors that will increase NOAA and DoD capabilities to perform their respective weather and oceanographic forecasting missions. These sensors will monitor atmospheric,



*Planned configuration of NPOESS C-2. C-2 will be launched into the 1730 orbit.*

climatic, oceanic, cryospheric, and near-Earth space weather developments. Observations will be made continuously, 24 hours per day - 7 days per week - 365 days per year to provide operational forecasters and scientists with daily "cat scans" that will enable us to gauge the status and health of our home planet.

The restructured NPOESS program provides for the initial acquisition of two spacecraft (C-1 and C-2). The government may exercise its option under the existing contract with NGST in 2010 to procure two additional NPOESS satellites (C-3 and C-4). The additional two satellites will extend the NPOESS constellation service life out to 2026. The first NPOESS satellite (C-1) is being planned for launch in 2013. As part of the NPOESS program, the IPO and NASA are jointly planning and building the NPOESS Preparatory Project (NPP) that is now scheduled to be launched in 2009. NPP will carry four NPOESS sensors to provide on-orbit testing and validation of sensors, algorithms, ground-based operations, and data processing systems prior to the launch of the first operational NPOESS satellite. The NPP satellite will be launched into the 1330 (1:30pm local time ascending) orbit to reduce the risk of a data gap between the last POES and the first NPOESS satellite.

The first operational NPOESS spacecraft (C-1) is expected to be launched in 2013 into a sun-synchronous polar orbit at an altitude of 828 km to replace the last of NOAA's POES (NOAA-N' that is scheduled for launch in 2009). Polar-orbiting satellites in sun-synchronous orbits pass over the same part of the Earth at roughly the same local time each day. NPOESS C-1 will be launched into an afternoon

orbit (1330 Local Time Ascending Node or LTAN), which means that the satellite will cross the Equator in its ascending orbit (moving from south to north) at 1:30PM local time on every orbit. This orbit, which is currently occupied by NOAA's POES (NOAA-18), is critical for global NWP models from which all operational weather forecasts are derived. The NPOESS C-2 satellite is being planned for launch in 2016 to replace the last of the DMSP spacecraft that currently occupy either an early morning (0530 local time descending node) or mid-morning (~1000 local time descending node) orbit to support military operations worldwide. NPOESS C-2 will cross the Equator in its descending orbit at 0530 (5:30 AM local time or 1730/5:30 PM LTAN). Satellite imagery and atmospheric data from this orbit are critical to support DoD (Air Force and Navy) global NWP models and short-term local and regional forecasts that are used for tactical planning on the battlefield.

An original objective of the NPOESS program was to operate a constellation of spacecraft in three equally spaced orbits (1330, 1730, and 2130 LTAN respectively) to provide global coverage with a data refresh rate (local average time interval between consecutive measurements of a parameter at the same location) of approximately four hours for most observations. The restructured NPOESS program will now provide for satellites in two orbits (1330 and 1730 LTAN, respectively). To provide coverage in the third orbit (2130/9:30PM LTAN or 0930/9:30AM local time descending node), the United States will partner with the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and rely on data from EUMETSAT's series of Meteorological Operational (MetOp) satellites that will fly in this mid-morning orbit. NOAA will process MetOp data and integrate into weather forecast models.

With the launch of EUMETSAT's first polar-orbiting meteorological satellite planned for October 2006, MetOp will replace the NOAA POES spacecraft in the mid-morning orbit as part of the NOAA/EUMETSAT Initial Joint Polar System (IJPS). The IPO plans to continue cooperation with EUMETSAT for a joint polar system as MetOp satellites carry US POES



instruments. During the transition to a future international polar satellite program, EUMETSAT's MetOp satellite will provide essential data in the mid-morning orbit for weather forecasting from its advanced sounding and imaging instruments. Data from EUMETSAT's MetOp satellite will increase the global coverage and refresh rate of the U.S. polar satellite system. In addition, the European meteorological community will receive valuable data from instruments on both the MetOp and NPOESS series of satellites.

The complement of sensors on board the NPOESS spacecraft will vary depending on orbit. NPOESS payloads include instruments to: 1) profile the atmosphere; 2) probe the space environment; 3) monitor the Earth's radiation budget; and 4) observe atmospheric, terrestrial, and oceanic phenomena globally. The first NPOESS spacecraft (C-1) will carry the following instruments:

**VIIRS** – The Visible/Infrared Imager Radiometer Suite collects radiometrically calibrated visible/infrared imagery and data. Data types include atmospheric, clouds, earth radiation budget, clear-air land/water surfaces, sea surface temperature, ocean color, and low light visible imagery. VIIRS contributes to 23 Environmental Data Records (EDRs) and is the primary instrument for 18 EDRs. VIIRS will combine the radiometric accuracy of the Advanced Very High Resolution Radiometer (AVHRR/3) currently flown on the NOAA polar orbiters with the high (0.65 km) spatial resolution of the Operational Linescan System (OLS) flown on DMSP. VIIRS will provide imagery of clouds under sunlit conditions in about a dozen visible channels (or frequency bands), as well as provide coverage in a number of infrared channels for night and day cloud imaging applications – particularly for the military. VIIRS will have multi-channel imaging capabilities to support the acquisition of high resolution atmospheric imagery and generation of a variety of applied products including: visible and infrared imaging of hurricanes and detection of fires, smoke, and atmospheric aerosols. VIIRS will also provide capabilities to produce higher resolution and more accurate measurements of sea surface temperature than are currently available from the heritage AVHRR/3 instrument on POES, as well as

an operational capability for ocean color observations and a variety of other products derived from observations of ocean color.

**CrIS** – The Cross-track Infrared Sounder (CrIS) collects atmospheric data to permit calculation of vertical profiles of temperature, moisture, and pressure at high spectral and temporal resolution. CrIS will provide improved measurements of temperature and moisture profiles in the atmosphere. Forecasters use temperature and moisture soundings (vertical profiles) in advanced NWP models to improve both global and regional predictions of weather patterns, storm tracks, and precipitation. The current High-resolution Infrared Sounder (HIRS/3) on POES provides data from about 20 infrared channels that are used to characterize atmospheric temperature profiles to an accuracy of 2 to 3 degrees Kelvin at a vertical resolution of about 2-3 km. Modern and future forecast models demand higher accuracy and higher resolution. The CrIS will provide over one thousand spectral channels of information in the infrared at an improved horizontal spatial resolution and will be able to measure temperature profiles with improved vertical resolution to an accuracy approaching one degree Kelvin. This improved accuracy is needed for increasingly sophisticated forecast models.

**ATMS** – The Advanced Technology Microwave Sounder (ATMS) will operate in conjunction with CrIS to profile atmospheric temperature and moisture. The ATMS is the next generation cross-track microwave sounder that will combine the capabilities of current generation microwave temperature sounders (Advanced Microwave Sounding Unit - AMSU-A) and microwave humidity sounders (AMSU-B) that are flying on NOAA's POES. The ATMS draws its heritage directly from AMSU-A/B, but with reduced volume, mass, and power. The ATMS has 22 microwave channels to provide temperature and moisture sounding capabilities. Sounding data from CrIS and ATMS will be combined to construct atmospheric temperature profiles at 1° K accuracy for 1 km layers in the troposphere and moisture profiles accurate to 15 percent for 2 km layers. Higher (spatial, temporal, and spectral) resolution and more accurate sounding data from CrIS and ATMS will

support continuing advances in data assimilation systems and NWP models to improve short- to medium-range weather forecasts.

**OMPS-N (nadir)** – The Ozone Mapping and Profiler Suite (OMPS) will use a nadir (downward-looking) scanning ozone mapper to monitor ozone concentration in the atmosphere from space. OMPS will collect total column ozone data and continue the daily global data produced by the current ozone monitoring systems; Solar Backscatter-Ultraviolet Spectral Radiometer (SBUV)/2, Total Ozone Mapping Spectrometer (TOMS) and EOS Aqua's Ozone Monitoring Instrument (OMI) but with higher fidelity. The collection of ozone data contributes to fulfilling U.S. treaty obligations under the Montreal Protocol to monitor ozone depletion in the stratosphere.

These four "core" instruments will also be flown on NPP beginning in 2009 to test, calibrate, and validate the sensors and algorithms in a non-operational mode and bridge measurements from NASA's Earth Observing System satellites to NPOESS. In addition to VIIRS, CrIS, ATMS, and OMPS, NPOESS C-1 will carry:

**SEM** – The Space Environment Monitor (SEM) is a multi-channel, charged particle spectrometer that measures the population of the Earth's radiation belts and the particle precipitation phenomena resulting from solar activity. SEM is currently flown on NOAA's POES and this capability to monitor the near-Earth space environment will continue on NPOESS.

**CERES** – The Clouds and the Earth's Radiant Energy System (CERES) is part of NASA's Earth Observing System (EOS) Terra and Aqua missions. CERES products include both solar-reflected and Earth-emitted radiation from the top of the atmosphere to the Earth's surface. Cloud properties are determined using simultaneous measurements by other EOS instruments such as the Moderate Resolution Imaging Spectroradiometer (MODIS) on Terra and Aqua. On NPOESS, CERES will work in conjunction with VIIRS to produce similar data products on the Earth's radiation.

**SARSAT** – The Search and Rescue Satellite Aided Tracking System (SARSAT) receives signals from emergency position



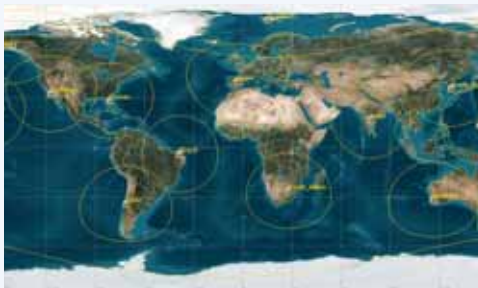
indicating radio beacons (EPIRBs) on international distress frequencies activated by aviators, mariners, and land-based users in distress. The satellite retransmits the emergency signals to a network of ground stations and ultimately to the U.S. Mission Control Center (USMCC) in Suitland, Maryland. The USMCC processes the data and alerts the appropriate search and rescue authorities (e.g., U.S. Coast Guard). The redesigned SARSAT subsystems on NPOESS will only support EPIRBs transmitting at 406 MHz.

**ADCS** – The Advanced Data Collection System (ADCS) relays meteorological and other data (e.g., temperature, humidity, pressure, velocity, salinity) transmitted from in-situ ground-based data collection platforms including buoys, free floating balloons, and remote weather stations. NPOESS will carry the upgraded ARGOS-3/4 data collection system that will provide two-way messaging capabilities for users to command and manage platform transmitters and sensors, as well as receive data efficiently from their platforms.

The second spacecraft in the NPOESS constellation (C-2) will be launched into the 0530 orbit and carry a subset of the C-1 instruments (VIIRS, SARSAT, ADCS) but will include a Microwave Imager/Sounder (MIS) that will also be flown on NPOESS C-3 and C-4. The MIS will carry forward capabilities for passive microwave sensing of such properties as precipitation and ocean surface wind speed that are currently measured by the Special Sensor Microwave Imager (SSM/I) and Special Sensor Microwave Imager/Sounder (SSM/I-S) on the DMSP spacecraft. Although significant development work was completed on a next-generation passive microwave imager/sounder (the Conical-scanning Microwave Imager/Sounder or CMIS) under the original NPOESS program, the contract for CMIS has been cancelled. Within the restructured NPOESS program, the IPO will start a new competition for acquisition of the MIS, with the first flight unit intended to fly on NPOESS C-2 in 2016.

In October 2006, EUMETSAT is planning to launch the first of its polar-orbiting MetOp satellites into a mid-morning orbit (0930 descending) to replace NOAA-17 and initiate the operational phase of the NOAA/EUMETSAT IJPS

partnership. The MetOp satellites are expected to have a nominal lifetime on orbit of five years with a six-month overlap between consecutive satellites, providing more than 14 years of on-orbit ser-



**SafetyNet™:** NPOESS will use an innovative globally distributed network of 15 unmanned, low-cost ground receptors. The data received by these receptors passes through existing commercial fiber optic networks to the four U.S. based environmental processing centers. These are the main data processing centers for weather data. SafetyNet™ is a patent pending technology of Northrop Grumman Space Technology.

vice life. By 2013 when the first NPOESS spacecraft is scheduled to be launched, the second MetOp satellite will be operational. The third MetOp satellite will be in orbit when NPOESS C-2 is launched in 2016.

The NPOESS ground system will be essential for command and control of the spacecraft and the reception, relay, and processing of the data collected by the satellites. The architectures for satellite command and control and ground processing are reasonably well defined for today's polar-orbiting spacecraft (POES and DMSP) and transmit data to the ground once per orbit. However, the methods for transmitting data from the satellite to the ground and relaying data to processing centers can be improved. For example, NOAA uses single ground stations to receive data from POES. This means that much data from orbit may be at least 101 minutes old before processing starts. As a result, perishable weather data may be rejected as input to NWP models. The high spatial, temporal, and spectral resolution of the instruments on NPOESS would be wasted if the data were not coupled with a significantly faster delivery system.

Global data from NPOESS spacecraft will be down-linked to 15 globally-dis-

tributed, unmanned ground stations that will be tied to four U.S. processing centers (Centrals) via commercial fiber-optic networks. This innovative "SafetyNet™" (patent pending technology) ground system is being developed by the NGST/Raytheon team and will deliver 77% of the global (daily average) data to Centrals within 15 minutes and 95% of the data (daily average) within 28 minutes from the time of on-orbit collection. This is a dramatic improvement over the ~120-180 minute data latency (time from observation by the satellite to availability of processed data) for global stored data from POES and DMSP. These significant improvements in data latency will allow for critical weather and environmental information to be used to update NWP models much more quickly at higher fidelity than today.

The ground system includes four Centrals that are responsible for processing and distribution of NPOESS data to end users. NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) will serve NOAA's National Centers for Environmental Prediction (NCEP) as well as U.S. civilian organizations. NESDIS is moving its satellite operations and data processing functions into a new NOAA Satellite Operations Facility (NSOF) in Suitland, Maryland. NSOF will house the NPOESS Mission Management Center (MMC) that will be responsible for command and control of the NPOESS spacecraft as well as management of the initial processing and relay of NPOESS data to the Centrals. The other three Centrals will support the U.S. military: the Air Force Weather Agency (AFWA); Fleet Numerical Meteorology and Oceanography Center (FNMOOC); and the Naval Oceanographic Office (NAVOCEANO).

In addition to the space-to-ground transmission of stored data, NPOESS will simultaneously broadcast two continuous real-time data streams, at high and low rates, to suitably equipped field terminals worldwide. NOAA's NESDIS will be responsible for providing access to the worldwide user community for near real-time processed NPOESS data and higher-level products. NESDIS will also maintain the long-term archive of NPOESS data through the Comprehensive Large Array Stewardship System (CLASS).



*The new NOAA Satellite Operations Facility, in Suitland, MD, is designed to receive multiple data sources from NOAA satellites, MetOp and others for processing and delivery to the NOAA Environmental Modeling Center (EMC) as critical input to weather prediction models as well as for distribution to the private sector.*

## The Climate Picture

Climate models are important tools for understanding how the climate operates today, how it may have functioned differently in the past, and how it may evolve in the future. This evolution is in response to forcings from both natural processes and human activities. Since the late 1960s and 70s when climate models were pioneered, their accuracy has improved as the number and quality of observations have increased, and as our theoretical understanding of the climate system has grown. Observations and data are the foundation of climate change science.

Today, operational earth-observing satellites provide over 99% of the observations used in computer-driven weather forecasts - the backbone of all weather predictions. The bulk of these observations come from polar-orbiting satellites. These systems also provide useful climate information, in particular on climate variations. The design lifetimes of the NPOESS spacecraft are about twice those of the current operational satellites; 5-7 years vs. 2-3 years. This is a significant advance for climate applications because it will reduce the uncertainty that results when records from successive satellite instruments are compiled to create a long-term climate data record. The NPOESS program will work to assure the continuity of observations from instruments on NOAA's POES, DoD's DMSP spacecraft, and NASA's EOS satellites that are essential for the construction of long-term climate data records.

The "core" instruments on NPOESS (VIIRS, CrIS, ATMS, and OMPS-N) will have much better spatial and temporal resolution, as well as more spectral channels of observation than their current operational counterparts. The continuation of the CERES instrument from EOS will provide continuity in the Earth radiation budget measurement.

Certain features in the design and operation of these instruments and spacecraft will improve the quality of measurements for use in climate monitoring and climate change assessment. For example, VIIRS will have on-board calibration of its visible channels, remedying a significant impediment to climate monitoring applications from its operational heritage instruments, the POES AVHRR/3 and the DMSP OLS. With its large number of channels coupled with more refined spectral resolution, CrIS will measure atmospheric temperature and moisture at better vertical resolution and with greater precision.

ATMS will continue and improve upon the measurements of NOAA's Microwave Sounding Unit (MSU) and AMSU instruments that for over 20 years have provided critical data on long-term changes in atmospheric temperatures. However, the trends derived from the MSU and AMSU observations are uncertain due to calibration problems and the drifting orbits of the NOAA POES spacecraft that result in a drift in daily observing time over the satellite's lifetime. For climate variables with diurnal variations, such temporal drifts can lead to artificial long-term trends. NPOESS satellites will maintain constant Equatorial crossing times and altitude throughout the mission lifetime, eliminating this problem. This capability to make measurements at "precisely" the same time each day is important to maintain consistency in the long-term data records required for climate change analysis and assessment.

## Benefits of NPOESS

NPOESS will support the operational needs of the civilian meteorological, oceanographic, environmental, climatic, and space environmental remote-sensing programs, and will provide global military environmental support. In addition, NPOESS data will be available to over 120 different nations around the

world in support of their environmental forecasting capabilities.

The advanced technology visible, infrared, and microwave imagers and sounders that will fly on NPOESS will deliver higher spatial and temporal resolution of oceanic, atmospheric, terrestrial, climatic, and solar-geophysical data, enabling more accurate short-term weather forecasts and severe storm warnings. These data will be assimilated into NWP models to improve short- (3-5 day) to medium- (7-15 day) range weather forecasts. The improved accuracy in atmospheric temperature and humidity soundings from these instruments, in combination with other observations expected to become available over the next ten years, will enable significant improvements in accuracy in these short to medium range weather forecasts.

NPOESS data will be used by DoD, NOAA, and private weather services to assist military and civilian aircraft in planning and executing the safest, fastest, and most fuel efficient routes; direct oceanic and Great Lakes shipping away from ice and bad weather; and assist farmers, builders, utilities, and other businesses affected by the weather. Improved real-time monitoring capabilities of NPOESS will help federal, state, and local agencies to reduce economic and life/safety impacts of floods, droughts, severe storms, and other weather-related hazards. Ultimately, NPOESS will help us "take the pulse of Planet Earth" by providing continuity of critical data for monitoring, understanding, and predicting climate change and assessing the impacts of climate change on seasonal and longer time scales.

## About the Authors

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At Northrop Grumman, the progress we make daily on NPOESS is crucial to bringing this next generation of low earth orbiting environmental satellites into service. NPOESS' state-of-the-art technology will deliver more accurate information in minutes, rather than hours, enabling decision makers to act quickly reducing potential loss of human life and property. In partnership with the Department of Commerce, the Department of Defense and NASA, the Northrop Grumman team is committed to developing a highly reliable national weather forecasting capability that saves lives and protects our economic well-being.

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